SPORT

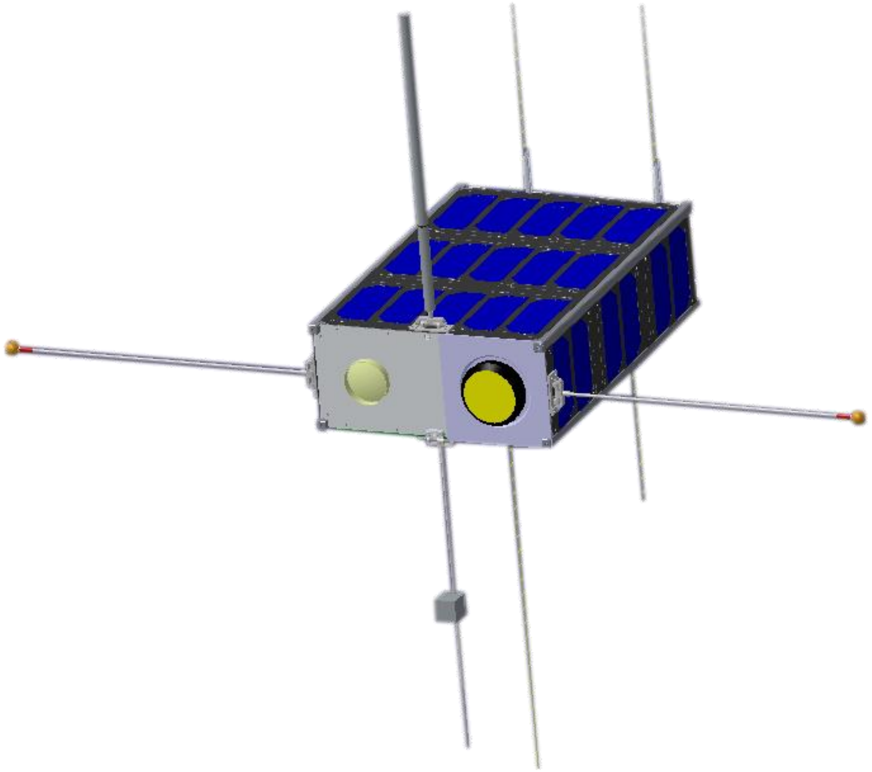
The Scintillation Prediction Observations Research Task

James F. Spann[1], Charles Swenson[2], Otavio Durão[3], Luis Loures[4], Rod Heelis[5], Rebecca Bishop[6], Guan Le[7], Abdu[4], Linda Krause[1], Clezio Nardin[3], Eloi Fonseca[4]

[1] NASA/MSFC, [2] USU, [3] INPE, [4] ITA, [5] UTD, [6] Aerospace, [7] NASA/GSFC

Outline

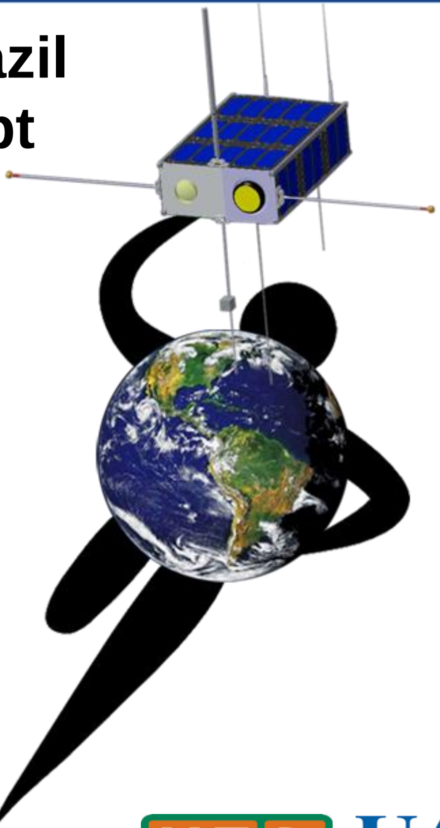
- Science
- Mission
- Instruments
- Spacecraft



SPORT

- **Joint United States / Brazil Science Mission Concept**

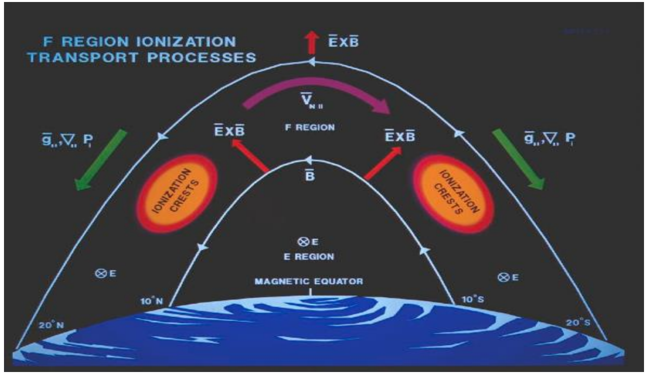
- **United States**
  - Science Instruments
- **Brazil**
  - Spacecraft
  - Operations



Joint Science Data Analysis

Science

- **The equatorial ionization anomalies**



Bela Fejer, The Equatorial Ionosphere: A Tutorial
CEDAR Meeting, Seattle Washington, 2015

- **Plasma Bubbles**

GUVI (Same Local Time, Different Longitudes)

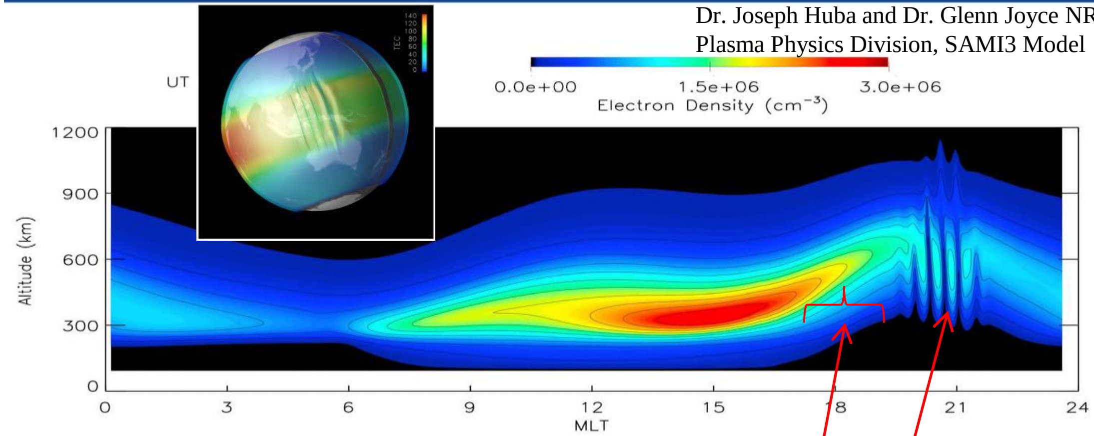
Why do bubbles form and sometimes not?

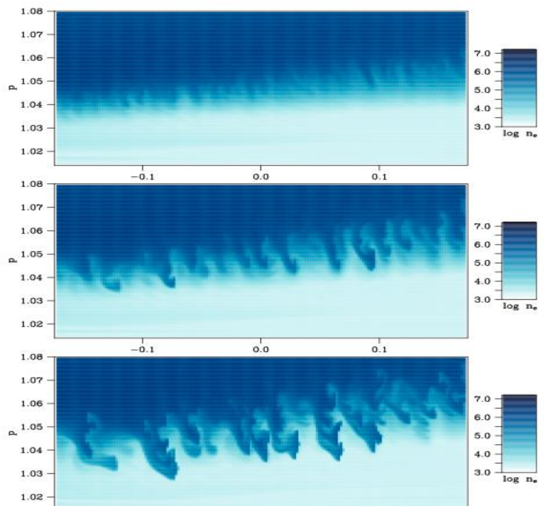
Kil, Hyosub, et al. "Coincident equatorial bubble detection by TIMED/GUVI and ROCSAT-1." Geophysical research letters 31.3 (2004).

Plasma Bubbles

About 1.5 Hours to form a bubble

Dr. Joseph Huba and Dr. Glenn Joyce NRL
Plasma Physics Division, SAMI3 Model

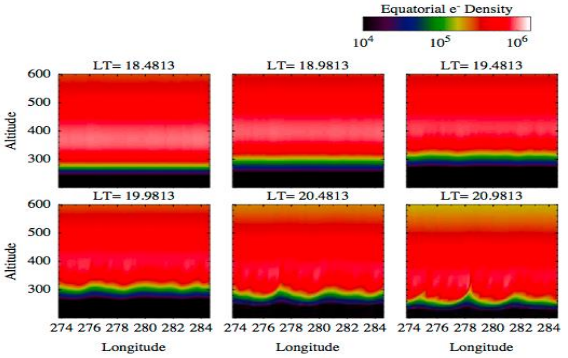




What is the state of the ionosphere here?

That leads to bubbles here ?

When bottom side seeding perturbations seem to always be present



Retterer, J. M., and P. Roddy. "Faith in a seed: on the origins of equatorial plasma bubbles." Annales Geophysicae. Vol. 32. No. 5. Copernicus GmbH, 2014.

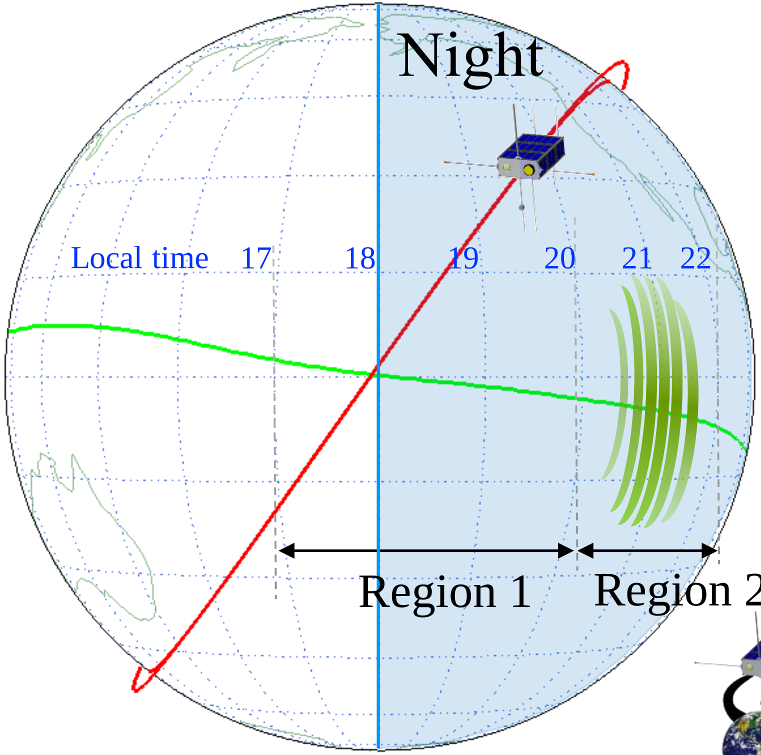
Science Goals

- **What is the state of the ionosphere that gives rise to the growth of plasma irregularities that extend into and above the F-peak?**

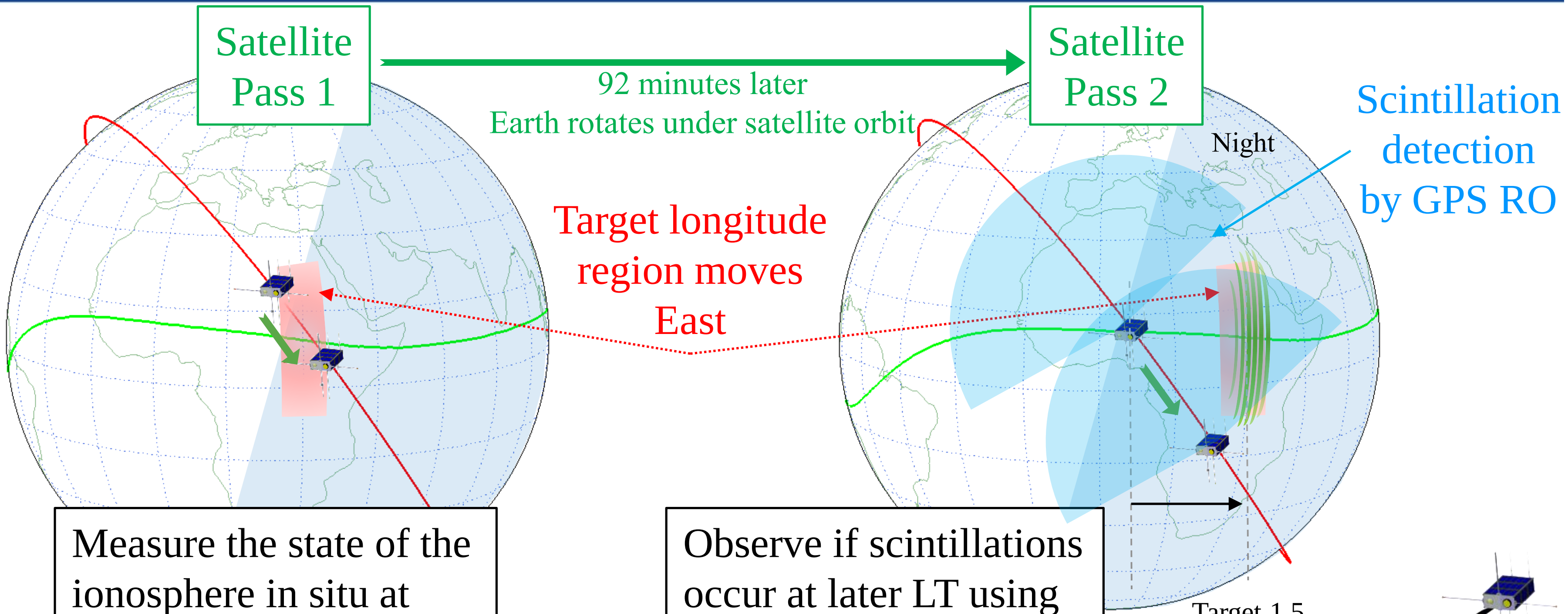
- **How do plasma irregularities evolve to impact the appearance of radio scintillation at different frequencies?**

SPORT Methodology

- **The state of the ionosphere at early local times is related to the occurrence of scintillations at later local times.**
  - How does this relation vary with longitude?
- **Use case studies when SPORT ascending or descending node is within 17 to 24 LT sector.**
- **Examine ~15 degree longitude sectors**



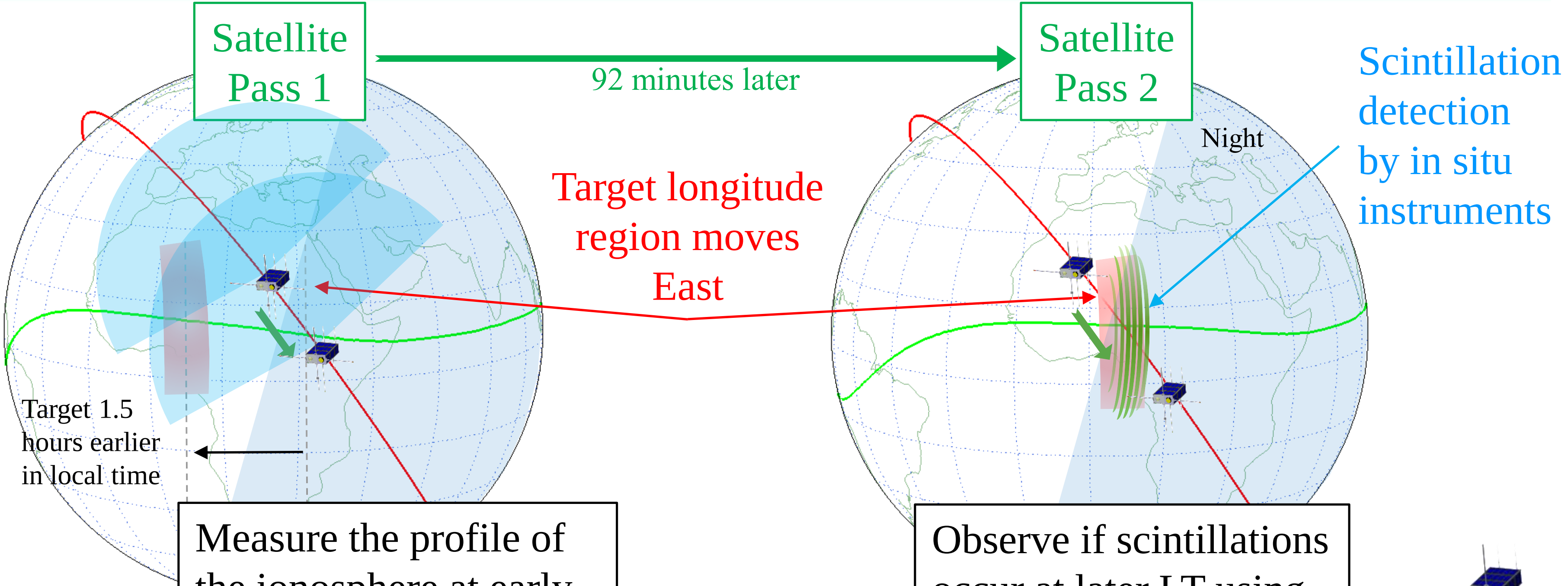
Methodology Strategy 1



Measure the state of the ionosphere in situ at early LT with SPORT.

Observe if scintillations occur at later LT using GPS RO from SPORT.

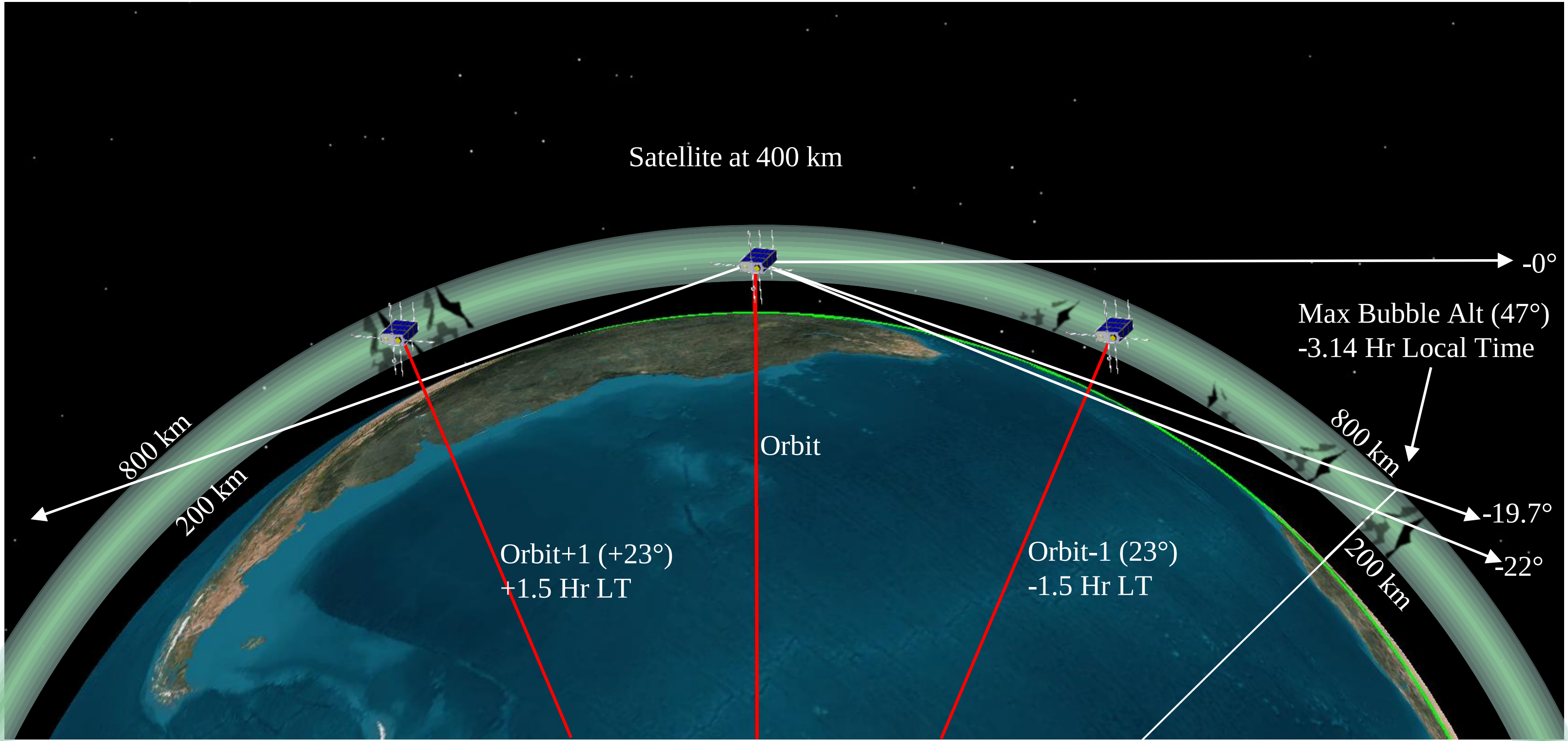
Methodology Strategy 2



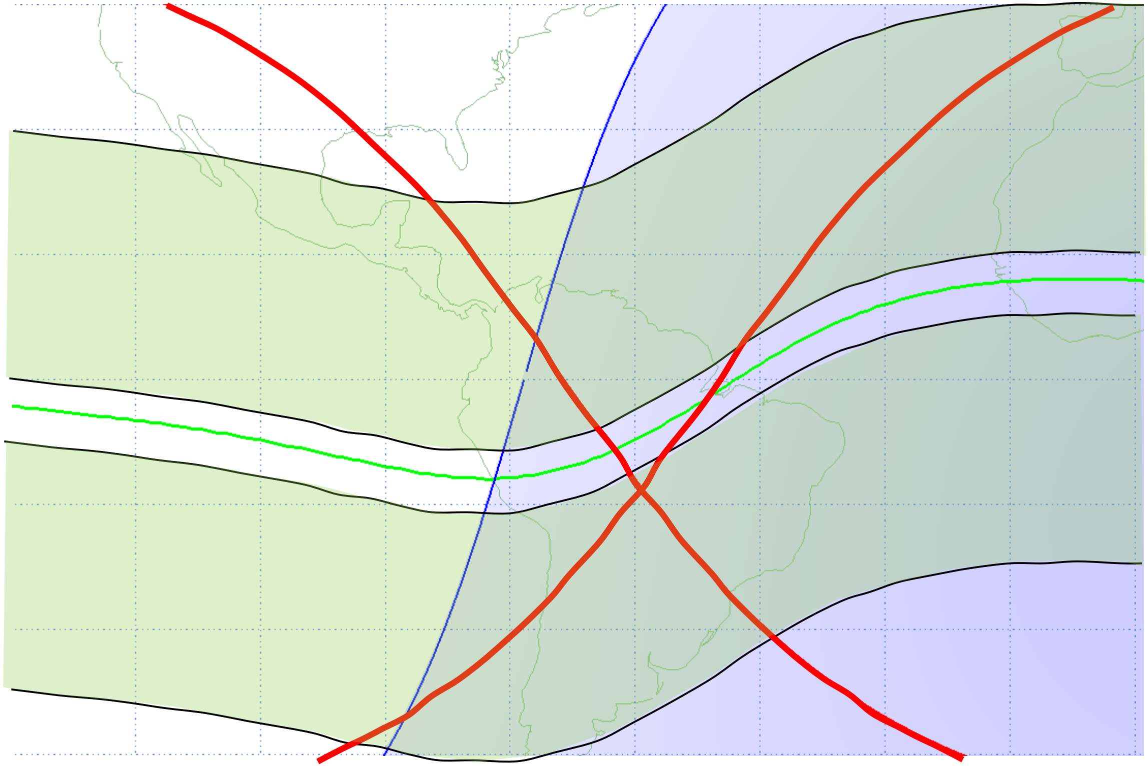
Measure the profile of the ionosphere at early LT with GPS RO.

Observe if scintillations occur at later LT using in situ instruments.

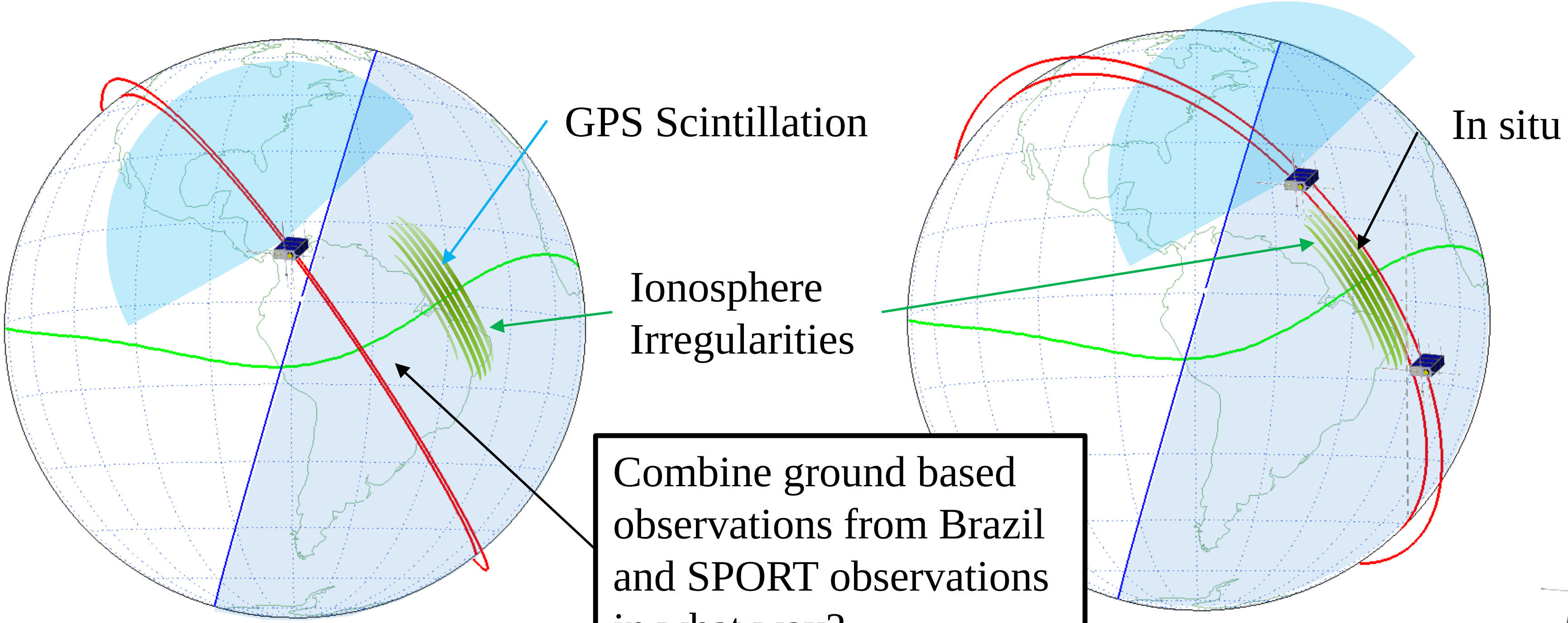
GPS Radio Occultation and Scintillation



In Situ + GPS RO + Ground Stations

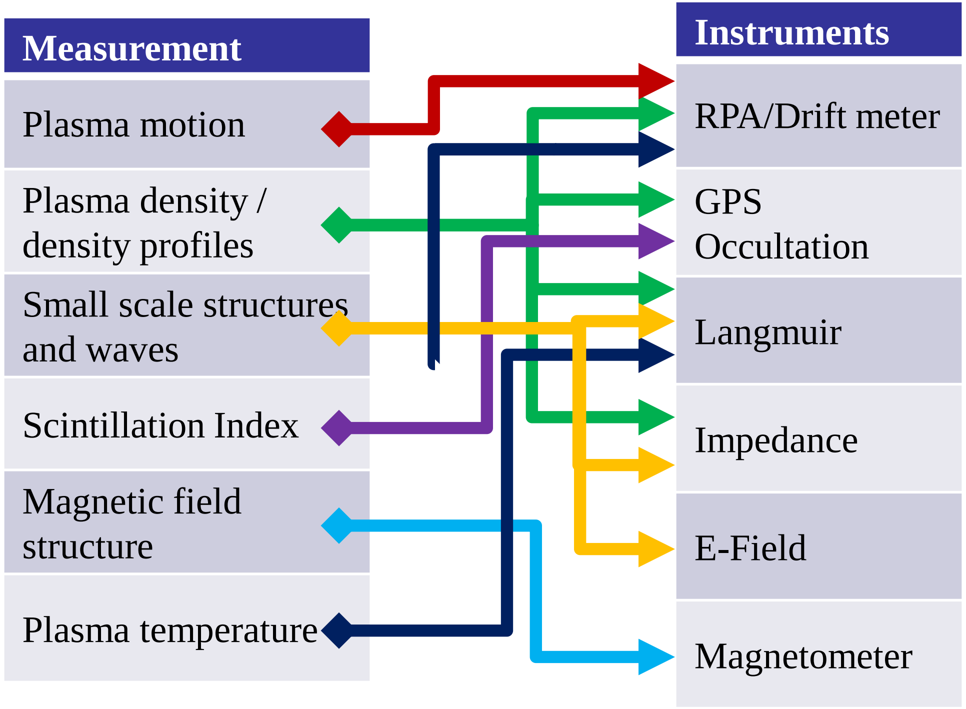


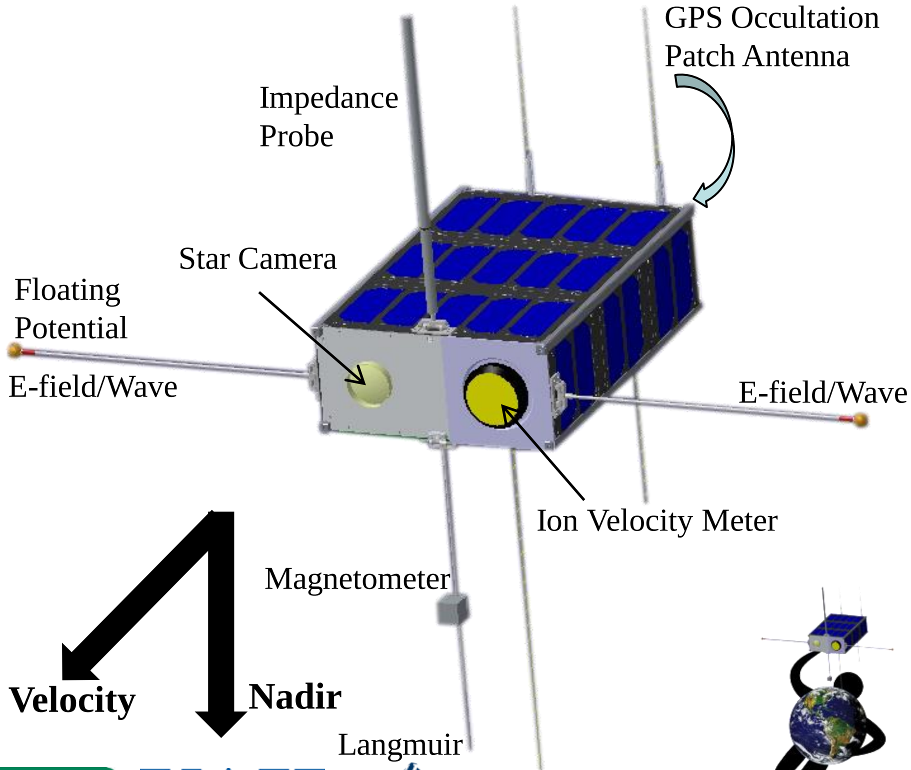
Methodology Strategy 3 ?



Combine ground based observations from Brazil and SPORT observations in what way?

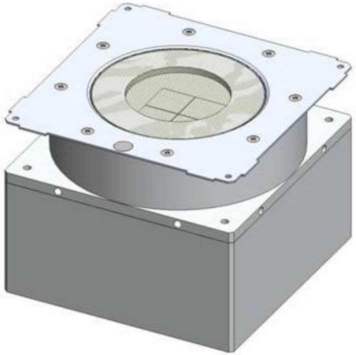
Measurement and Instrumentation



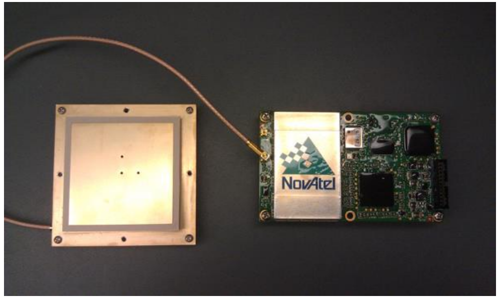


SPORT Instruments

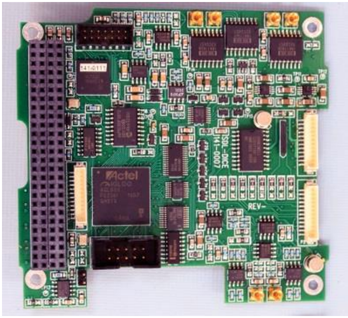
Ion Velocity Meter
UTD

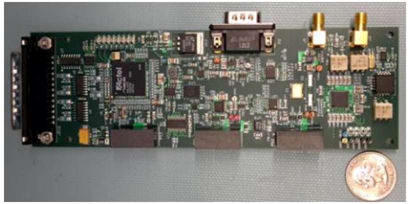


GPS Occultation
Receiver
Aerospace

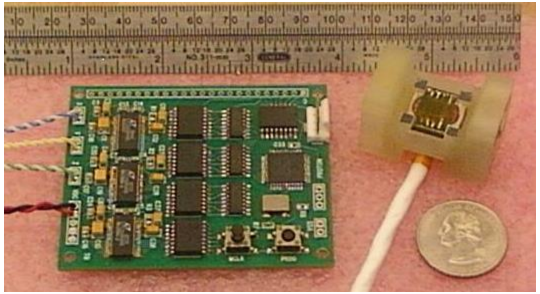


Langmuir, E-field,
Impedance Probe
USU

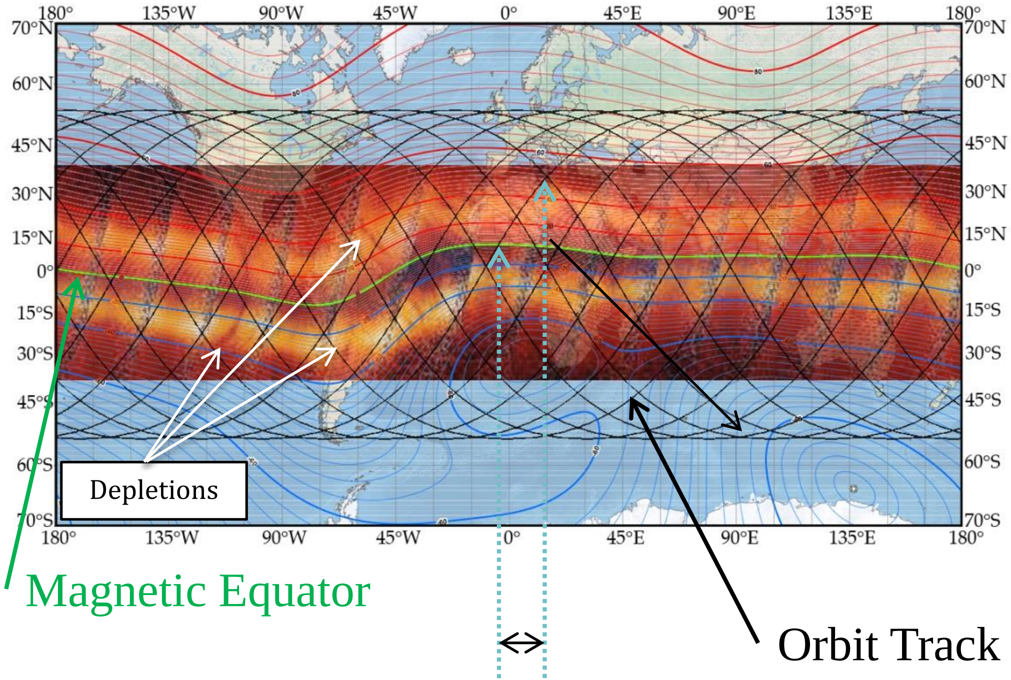




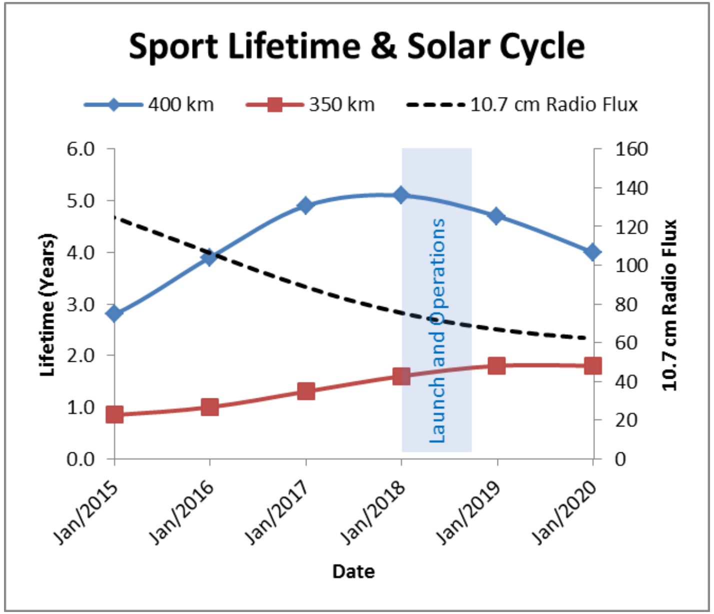
Fluxgate Magnetometer
NASA Goddard



SPORT Mission and ORBIT



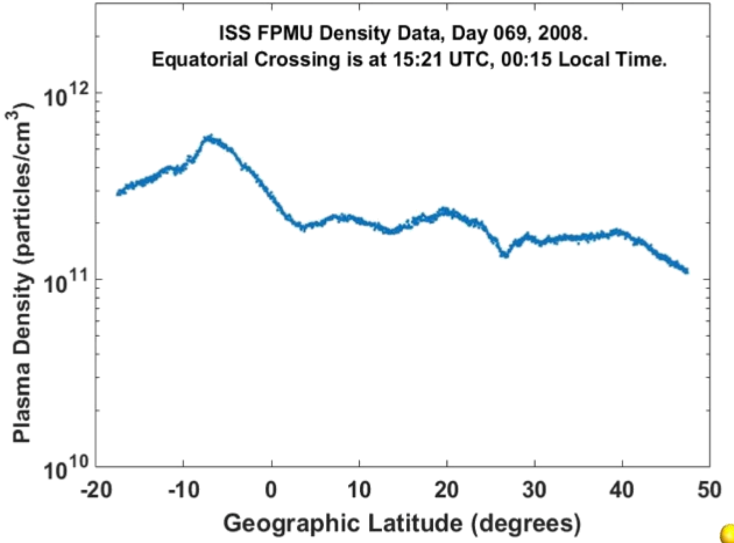
20° latitude or 1.3 hr LT across an EIA arc

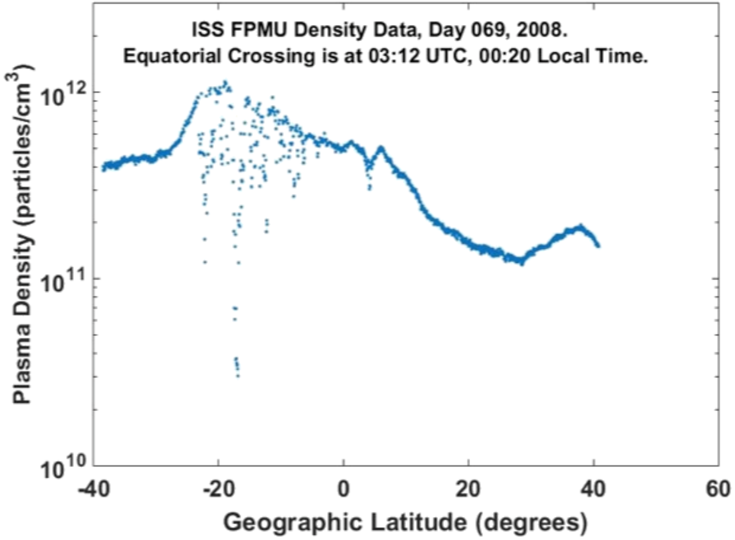


Launch from ISS, 400 km Alt
~3 year life

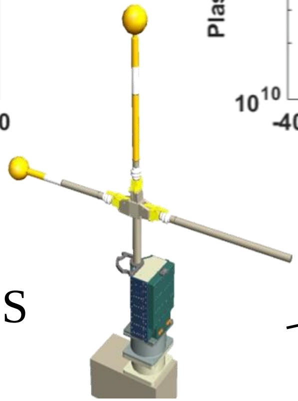
NASA AEROSPACE UTD UAH The University of Alabama in Huntsville UtahStateUniversity

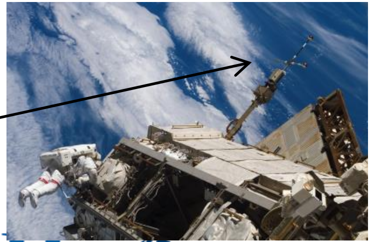
Example Data from ISS Orbit



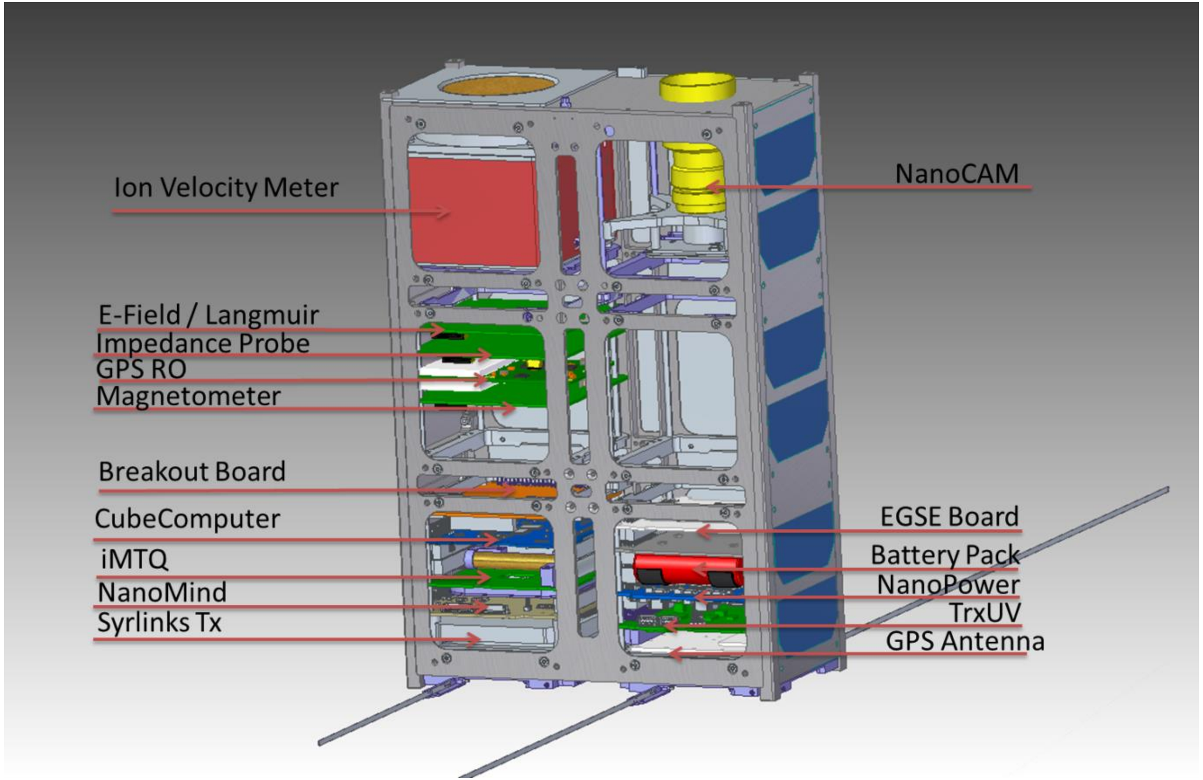


Data from the FPMU on the ISS





Sport Instrument Accommodation

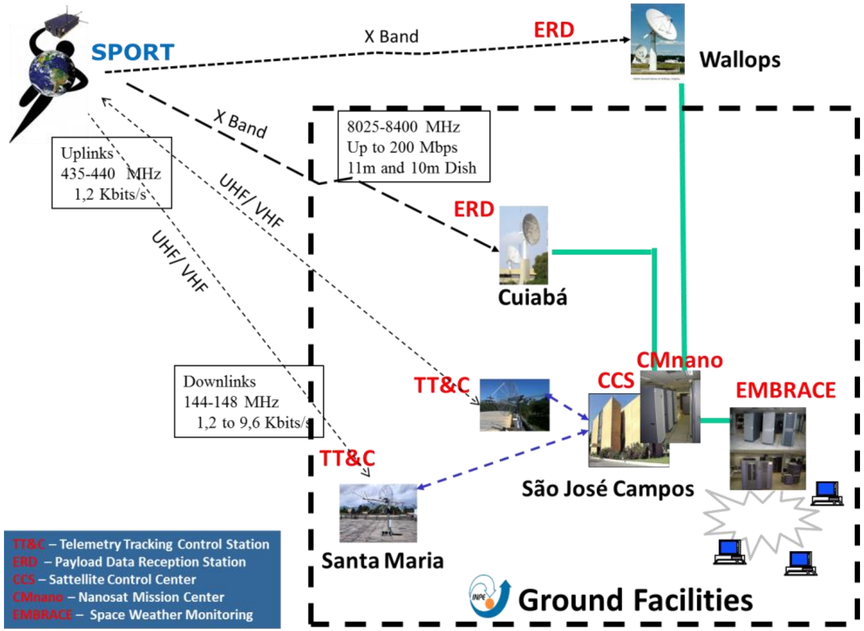


Worst case power operating concept

Science Payloads Power Requirements				
Current Best Estimate (Watts)				
Component	TRL	Peak	Duty	OAP
IVM	5	0.30	100%	0.30
GPS RO	8	1.50	50%	0.75
Langmuir	8	0.15	100%	0.15
E-Field	8	0.15	100%	0.15
Impedance	5	0.40	20%	0.08
Science Mag	6	0.45	100%	0.45
Star Camera	8	0.65	20%	0.13
Total		**3.60**		**2.01**

SPORT Telemetry

Channel Name	Duty %	Rate Hz	Bit Rate bps	Alongtrack km
Ion Velocity Meter			**1824**	
Drifts	100%	2.00	288	3.83
Composition Sweeps	100%	2.00	1536	3.83
GPS RO			**16000**	
Dayside Tracking	50%	1.00	1000	7.66
Nightside Tracking	50%	50.00	15000	0.15
Langmuir Probe			**1984**	
DC Probe	100%	40.00	960	0.19
IV Sweeps	100%	0.04	491.52	191.43
Floating Probe Sweeps	100%	0.04	491.52	191.43
N_e Wave Power	100%	0.04	40.96	191.43
E-Field			**1321**	
DC field	100%	40.00	1280	0.19
E-Field Wave Power	100%	0.04	40.96	191.43
Impedance Probe			**197**	
I & Q Sweep	20%	0.04	196	191.43
Tracking	20%	40.00	192	0.19
Fluxgate Magnetometer			**2880**	
DC field	100%	40.00	2880	0.19
Star Imager			**1500**	
Star Subimage	100%	1.00	1500	7.66
Other			**2624**	
Science GPS timeing	100%	40.00	2560	0.19
Science Housekeeping	100%	0.10	64	76.57
Rate collected on orbit			**31210**	



50 Mbit/second Downlink giving a safety factor of 14

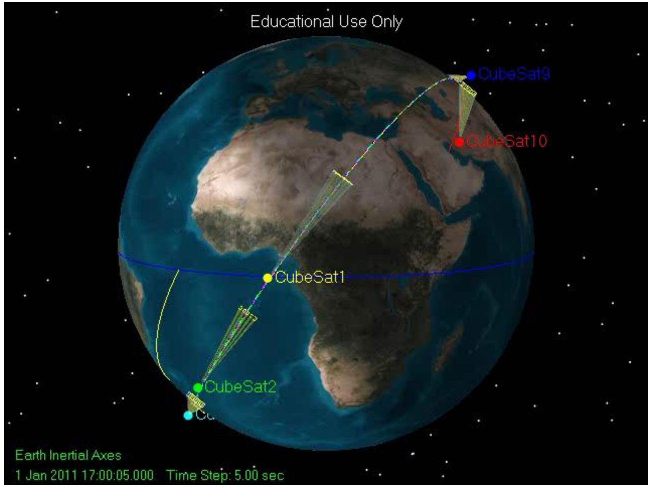
Expected instrument Performance

Expected Instrument Performance and Requirements						
Parameter	**Ion Velocity Meter**	**GPS Occultation**	**Electric Field Probe**	**Langmuir Probe**	**Impedance Probe**	**Magnetometer**
Scientific Requirement	V_i: ±800 m/s, 20 m/s ΔN_i: 10^4 to 10^7 cm^{-3}	N_e-Profile: 10^4 to 10^7 cm^{-3} S4 0.2 to 1.2	0.1 to ±45 mV/m	ΔN_e : 10^3 to 10^7 cm^{-3} ΔN_i: 10^3 to 10^7 cm^{-3}	N_e : 10^3 to 10^7 cm^{-3}	± 56,000 nT, 100 nT
Instrument Performance	V_i: ±1000 m/s, 15 m/s ΔN_i: 10^2 to 10^7 cm^{-3}, 5% T_i: 250 to 5000 K C_i : 0-100%, 1-40 amu DC to 2 Hz	Scintillations (S4) Slant TEC: 3 to 200 units N_e-Profile: 10^3 to 10^7 cm^{-3} S4 0.1 to 1.5 σ: 0.1 to 20 rads 50 Hz	0.1 to 500 mV/m, 1% V_i (derived): 20 m/s DC-40 Hz 16 spectrometer ch. 20 Hz to 15 kHz	ΔN_e : 10 to 10^7 cm^{-3}, 5% ΔN_i: 10^3 to 10^9 cm^{-3}, 5% T_e : 200 to 5000 K V_f : ±10 mV to ± 12 V V_p: ±10 mV to ± 12 V DC-40 Hz, 25 s/sweep 16 spectrometer ch. 20 Hz to 15 kHz	N_e : 10 to 10^7 cm^{-3}, 1% DC-40 Hz, 25 s/sweep	± 64,000 nT, 10 nT DC-40 Hz
Mechanism	8 cm aperture	7.6 x 7.6 x 0.5 cm patch antenna	Two 30 cm booms	0.3 x 30 cm boom	30 cm boom	25 cm boom
Attitude Control	15° pointing control	15° pointing control	15° pointing control	15° pointing control	15° pointing control	NA
Attitude knowledge post processed req.	0.02°	2°	0.02°	10°	10°	2° pointing
Field of View	30°	160°	180°	180°	180°	180°
Peak Power	0.3 W	1.5 W	0.15 W	0.15 W	0.4 W	0.45 W
Volume	1.0U Cube 9 x 9 x 10 cm	~0.15U Cube 1.5 x 9 x 9 cm	~0.1U Cube (Shared with LP) 0.75 x 9 x 9 cm	~0.1U Cube (Shared with E-Field) 0.75 x 9 x 9 cm	~0.1U Cube 0.75 x 9 x 9 cm	~0.5U Cube 5 x 9 x 9 cm
Mass	< 1000 g	< 200 g	< 80 g (shared)	< 80g (shared)	< 160 g	< 150 g
Data Rate	2.0 kbps	1.0 kbps Day; 15 kbps Night	1.4 kbps	2.0 kbps	1 kbps	2.8 kbps
Horizontal Cell Size	100 km	500 km	200 m; 20 m spectrometer	200 m; 20 m spectrometer	190 km	10 km
Vertical Cell Size	NA	30 km	NA	NA	NA	NA

V_i – ion drift velocities; ΔN_i – relative ion density; ΔN_e – relative electron density; T_e – electron temperature ;T_i – ion temperature ; V_f – floating potential ; V_p – plasma potential ; N_e- electron density; B-Magnetic Field ; TEC – total electron content; C_i – Ion composition; DC – 1D DC Electric Field;, S4 – RF signal amplitude index, σ – RF signal phase index,

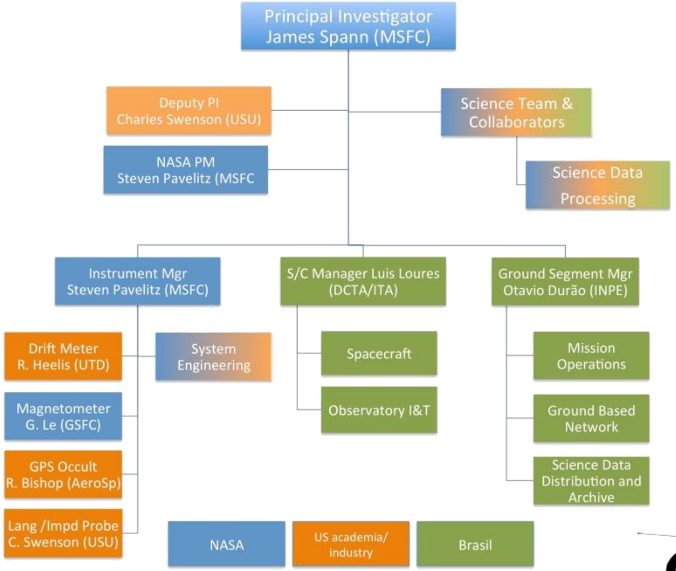
Conclusions

- CubeSats mission can be developed with a full/regular suite of science instruments.
- Mid inclination ISS orbits allow for the deconvolution of local time and longitude at low-latitudes
- A String of pearls mission to increase time resolution



SPORT Team and Functions

- **MSFC**
  - PI, PM, Science Co-I, single interface to Brasil, Engineering oversight of instruments and observatory I&T, Launch and DoD coordination
- **Instruments** – Each instrument has a US and Brasil science counterpart
  - Utah State: Deputy PI, Langmuir and Impedance Probe, Star Camera
  - Aerospace Corp – Co-I, GPS Occultation
  - University of Texas at Dallas – Co-I, Drift Meter
  - GSFC – Co-I, Magnetometer, Data Archival at SPDF
- **UAH**
  - System Engineering Support
- **ITA**
  - Spacecraft, Observatory I&T
- **INPE**
  - Ground observation network, Mission Ops, Data management and distribution/archive



AEROSPACE UTD UAH The University of Alabama in Huntsville UtahStateUniversity